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Zone 4 Study: Shielded Lift Truck Refurbishment / Replacement

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Shielded Lift Truck
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Abstract

The Zone 4 Stage Right Shielded Lift Trucks (SLT's) will likely need refurbishment or replacement within the next two to five years, due to wear. This document discusses the options to provide a long term and reliable means of satisfying Zone 4 material movement and inventory requirements.

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1 Executive Summary

The Zone 4 Stage Right Shielded Lift Trucks (SLT's) will likely need refurbishment or replacement within the next two to five years, due to wear. This document discusses the options to provide a long term and reliable means of satisfying Zone 4 material movement and inventory requirements. The options considered were:

1) Refurbishing existing vehicles and shielding

2) Building new vehicles with new shielding based on the current SLT design

3) Building new vehicles with a lightweight shielding that selectively attenuates radiation in the spectrum typically emitted from pits

4) Developing a remote controlled vehicle

Each option was assessed using performance, time, and cost attributes. From these comparisons the following observations emerged.

> Option 1 is not viable because there is no method to adequately refurbish the shielding. Further, the electronics are obsolete and will require upgrading to be maintainable.
>
> The shielding for Options 1 & 2 is problematic because the mechanical material properties are not suitable for the application.
>
> Selective spectrum shielding is promising and may be performance and cost competitive with other options. However, no data exits to validate this option making an experimental phase imperative prior to pursuing this option.
>
> A remote controlled vehicle is potentially the preferred solution from the operator's standpoint but has higher development costs. The operator's preference is primarily due to the extended number of hours required to perform inventory operations while seated inside the non-climate controlled SLT, which can amplify the climatic conditions found in the high plains of Texas.

Interestingly, the remote controlled option could prove to be the easiest to move forward when all considerations are taken into account. Sandia considers remote controlled industrial vehicle technology to have a wide range of applications. Further, Sandia has committed to procure the hardware required to mature this technology. If funding could be directed to target Zone 4 as an initial operating capability it may be possible to use the development vehicle for Zone 4 inventory validation testing under the direction of Sandia; thereby, demonstrating the process so that ultimate review and approval could be accelerated.

2 Introduction

The purpose of this study is to evaluate a range of solutions that provide Pantex Plant a long term and reliable means of satisfying Zone 4 material movement and inventory requirements. To perform the evaluation, performance attributes for each option are compared. This report discusses each of the parameters and how the parameter affects the selection of an option. Finally, supporting documentation is presented in a series of appendices.

3 Option Trade-off Matrix

The following matrix summarizes various options for vehicle refurbishment or replacement. The four options (Refurbishment, New vehicle, Lightweight shielding, Remote operation) and three parameters (Time, Cost, Performance) are discussed in detail in the rest of the document.

Time	**Refurbishment**	**New vehicle**	**Lightweight shielding**	**Remote operation**
Development	Low	Medium	High	Medium
Implementation	Medium	Medium	Medium	Medium
Approvals	Low	Low	Medium	High
Expected life	Low	Medium	High	High
Development risk	Low	Low	High	Medium

Cost				
Development $	Low	Low	Medium	High
Replication $	Low	Medium	Medium	Low
Maintenance level	High	Medium	Low	Medium

Performance				
Shielding	Full spectrum	Full spectrum	Selective	N/A
Ergonomics	Poor	Poor	Poor	Good
Operator perception	OK	OK	OK	Good
Pre-op time	Good	Good	Good	OK
Process time	Good	Good	Good	Inventory=Good Move = OK
Design for sunset	Poor	OK	OK	Good

4 Options

Four options were evaluated for extending the life of the Stage Right Shielded Lift Trucks, which are used for material movement and inventory in Zone 4. The four options do not depict the entire range of possible solutions but do span the breadth of viable solutions. A detailed discussion of each option follows.

4.1 Refurbishment

> Refurbish existing vehicles by repairing worn shielding and replacing broken parts. A primary aim is to repair the original NS-4-FR neutron shielding material. Replacing the vehicle electronics is possible but not necessary.

This option involves repairing or replacing worn and broken parts on the SLT's currently in use. A primary aim of this option was to repair the damaged NS-4-FR shielding; however, repair is not feasible and this option will require replacement of the shielding. Other mechanical parts of the vehicle will also be repaired or replaced. Currently, the original STD-bus vehicle electronics are obsolete meaning replacement parts are not longer available. However, the electronics are functional and could continue to be used at the risk of being un-maintainable.

Advantages
This is the least expensive option and likely could be done in the least amount of time since no additional development must be done.

Disadvantages
The current SLT's will be out of service while being refurbished. The longevity of the system will not be significantly increased.

4.2 New vehicles

> Build new vehicles based on the original SLT design and install new shielding and new vehicle electronics.

This option involves building new SLT's based on the original SLT design. The shielding will be the same composition, thickness, and weight as the original. Since the original molds for the shielding are no longer available, new molds will have to be made. The original STD-bus vehicle electronics are no longer available, so the computing platform will have to be replaced with an updated model. This will require minimal (but some) software development to take into account minor differences in the new vehicle electronics versus the old.

Advantages
The new vehicles will be usable for a longer time before replacement is required. Replacement of the vehicle electronics with updated, long-lifetime components will reduce long-term maintenance costs. No current vehicles must be taken out of service while this option is developed.

Disadvantages
This option will take longer to develop than would simple refurbishment because the existing SLT base vehicle is no longer available. Using a newer model vehicle will require redesign of the shielding and shield attachment hardware. The new vehicles will be nearly identical to the old vehicle's maximum payload capacity. Thus, the weight-related wear that occurred with the original SLT's is likely to occur with this vehicle.

4.3 Light weight shielding

Build new vehicles and new vehicle electronics with new lightweight shielding.

This option involves building new SLT's with new shielding and new vehicle electronics. The new shielding will be of a different composition than the original. Rather than shielding against the entire radiation spectrum, it will be designed to shield selectively against the portions of the spectrum that are naturally emitted by pits and are damaging to humans.

Advantages
The new shielding will be substantially thinner and lighter than the current shielding. Light weight shielding will lead to reduced wear on the vehicle which in turn leads better vehicle performance, longer expected lifetime, and lower maintenance costs.

Disadvantages
The time required to obtain approvals for this system may be greater than for the NS-4-FR-shielded lift trucks because of the new type of shielding proposed. However, backed with proper scientific documentation, it is believed that a solid case may be made to the authorizing agencies for approval.

4.4 Remotely operated

Build new vehicles and vehicle electronics that the operator drives remotely from an operator control station. The control station sends commands to the vehicle and conveys information back to the operator. Since the operator is no longer on board the vehicle, no shielding is required for the lift truck.

This option involves building new vehicles, but with no shielding. The operator drives the system remotely using an operator control station. The operator may be located in a shelter or in a vehicle outside the magazine. The operator control station could be connected to the lift truck by cable or wireless communication.

Advantages
The operator is no longer confined on board the lift truck. The improved working environment increases operator endurance. The SLT operators prefer this option.

Disadvantages
Development cost is higher with this option since the control components of the system are new developments. The time required to obtain approval for this system is anticipated to be the greatest of the proposed systems, because it will likely constitute a change in the process, thus requiring a more rigorous approval process. However, precedence for automated systems exists at Pantex (AGGDIS, WALS, SR2, etc.) indicating the feasibility for acceptance of the remotely operated option.

5 Parameters

This section discusses each performance attribute and evaluates how well each option satisfies each attribute, as well as the reasons for the ratings.

5.1 Time

Development time

> This is the time required for developing and demonstrating the technology and engineering of the system.

The refurbishment option has the shortest development time because it uses existing components except for the molds for the shielding. The development time for the new vehicle option will be slightly longer since drawings for installation on the new model vehicle will be required well as molds for the shielding. The lightweight shielding option is a new concept and will require significant time to optimize, test, and design the shielding package. The remote operation option will take time to design and test but the ISRC has implemented this type of technology on numerous different vehicles.

Implementation time

> This is the time required for fabricating a production vehicle and performing on-site installation and testing.

Although the tasks for each option are different, the implementation times would be comparable. For the refurbishment option, the vehicle would have to be stripped, repaired, and re-assembled. For the new vehicle and for the lightweight shielding options, the truck procurement and shielding fabrication could be done in parallel thereby minimizing the overall time. For the remotely operated vehicle, implementation of the software would be the rate-determining task; however, the truck procurement could be done in parallel as well.

Approval time

> This is the time required for obtaining all levels of approvals to install the system on-site and start operations.

The refurbished and new vehicle options would require little time to approve because they are very similar to the existing vehicles. The lightweight shielding option is operationally equivalent to the existing vehicles but could require a more in-depth review of the shielding. The remotely operated system is a different operational concept, thus approval time could be the longest.

Expected life

This is how long the mechanical parts of the system are expected to keep working.

For the refurbished and new vehicle options the length of service would be negatively affected by the heaviness of the shielding and the poor durability of the shielding as compared to the lightweight shielding and remote controlled options. Further, the refurbished vehicle has already been used a number of years so it would not be expected to last as long as the new vehicle option.

Development risk

This is the risk of being unable to produce a system with the required performance with the given budget and time. Typically this is proportional to the amount of new technology being developed or used. This reflects the degree to which a showstopper could force the project team to switch to a different option.

The development risk for the refurbished and new vehicle options is low since they are effectively identical to the current system. The remote controlled option is a medium risk because it is a new operational concept even though the technology is well proven. Risk is high for the lightweight shielding option since no data currently exists to validate this option.

5.2 Cost

Development cost

This is the cost of designing, developing, and testing the option.

Since the refurbished and new vehicles are the same as the existing system the main development cost would be the fabrication of the mold for producing the shielding. The lightweight shielding option development cost would be higher due to the design and testing of the shielding. The development for the remotely operated vehicle would be fairly significant because of the design, implementation, and testing of the software for remote control.

Replication cost

This is the cost of producing additional systems once development and design is complete.

The major costs associated with the refurbishment option are shielding fabrication and base vehicle refurbishment. The major costs associated with the new vehicle option are shielding fabrication and new vehicle procurement, with procuring a new vehicle costing more than refurbishing an existing vehicle. The lightweight shielding option includes the cost of a new vehicle and the cost of the lightweight shielding, which is expected to be somewhat less than the cost of replacement shielding. The remote operation option is fairly inexpensive to replicate because it does not require shielding.

Maintenance cost

This is the cost of keeping the system operational, which includes the expected frequency of maintenance as well as the cost of parts and labor.

The refurbishment option uses base vehicles and electronics that have seen a decade of use, thus it is reasonable to expect maintenance costs to be the highest of all options. The new vehicle option uses new base vehicles and electronics but uses the heavy shielding, which causes maintenance problems. The lightweight shielding option would require less maintenance because of the weight and simplicity of the system. The remotely operated vehicle is also lightweight, but the system would contain more high technology components.

5.3 Performance

Shielding

This is the range of the radiation spectrum for which the operator is protected. Full spectrum coverage shields the operator from a large range of radiation. Selective spectrum coverage shields the operator from those energy levels, which the operator is exposed to during material movement and inventory operations. The remote operation option removes the operator from the radiation environment. It is expected that the occupational dose to the operator for all proposed options would be similar.

Ergonomics

This is how easy and comfortable the system is to operate. In general, the better the ergonomics, the longer an operator can run the system. This refers mainly to the physical working environment and system interface.

The remotely operated vehicle is the best ergonomically for the operator because the operator is located outside the vehicle where he can either move and stretch or sit in a climate controlled pickup. With the other options he is confined to a shielded non-climate controlled vehicle for extended periods of time.

Operator perception

This is how well the operator can perceive operations of the system. It is related to ergonomics, in that better ergonomics generally lead to greater operator performance. However, other factors such as the required level of concentration also affect operator perception.

In the shielded vehicle options the operator’s perception is severely limited due to the poor visibility resulting from the shielding. The current shielded vehicle employs sensors to provide the additional perception needed for operations. The remote operation option will provide specific camera views to the operator by which the operator’s perception will be greatly enhanced.

Pre-op(eration) time

> This is the time required to perform pre-operational checks and prepare the vehicle to begin operations.

For the shielded vehicle options the pre-operational time would be the same as for the current system. The remote operation option would take longer because the remote control subsystem would have to be connected and checked in addition to the vehicle.

Process time

> This is the time the operator spends operating the vehicle in performance of an operation. It starts after all the pre-operational checks have been performed, and terminates when all operations in a magazine are complete.

The process time for the shielded vehicle options would be the same because they use the exact same operational concept at the current system. The remote controlled option would have similar process time for material movement as the other options because even though the process is remote perception is improved. The remote controlled option would have a faster process time for inventory because the need for rest breaks could be eliminated.

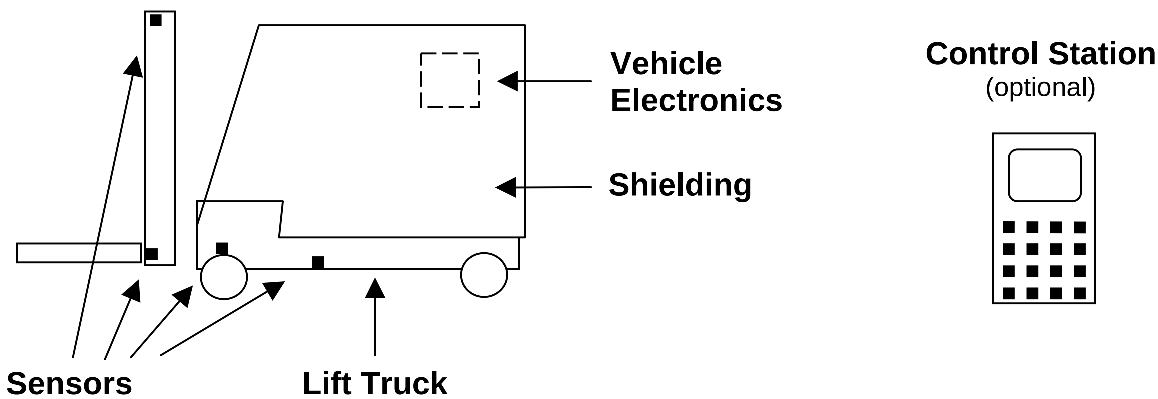
Design for sunset

> This is design in such a way that takes into account the possibility/probability that electronic hardware and software will become obsolete during the lifetime of the system. Design choices are made such that hardware can be upgraded or replaced with minimal impact on the system.

The electronics on the existing system are obsolete making design for sunset poor. The electronics for the new vehicle and lightweight shielding options would be upgraded to state-of-the-art electronics; however, sunset will occur do to the architecture of the system. The remote operation option could be designed with less sensitivity to sunset as a criterion.

6 System Components Overview

The Shielded Lift Truck system can be broken down into components, which can be considered independently for replacement or refurbishment. The following is a rough diagram of these components, followed by a descriptive section on each.



6.1 Lift Truck

The lift truck is a commercially produced vehicle. It is purchased “off the shelf” and modified for material movement by fitting it with radiation shielding, sensors, and electronics.

Current
The current lift truck is from Hyster.

Potential
There have been no quality, performance, or long-term support problems with the current lift trucks, so there are no plans to procure lift trucks from another manufacturer.

6.2 Shielding

Shielding is required on the vehicle to protect the operator from radiation during material movement and inventory operations.

Current
NAC International manufactured the NS-4-FR shielding material on the current SLT’s in 1996. It is also known as Bisco shielding, after the company who made the original formulation. It is polymer-based with 18.5% tungsten content, and it shields

against a wide radiation spectrum. It is functionally more than adequate for use on the SLT, but the composition and weight of the shielding are inappropriate for the mobile application on the SLT. The heavy use and rough handling has caused the shielding to crack, while the tremendous weight has severely impacted SLT driving performance. The current shielding is a maximum of about 8 inches thick and weighs over 9,000 pounds. Before new shields could be produced new casting molds must be fabricated because the original molds are no longer available. The time from order placement to delivery of new shields is quoted at 4 months.

Potential
A lightweight, cadmium-based neutron shielding material is proposed to attenuate only the radiation that is naturally emitted by pits and is dangerous to humans. To maintain the same occupational dose as that experienced by current SLT operators, the thickness and weight of this shielding will be substantially less than for the NS-4-FR material, on the order of 0.25 inch and would weigh about 1,500 pounds for equivalent protection.

6.3 Vehicle Electronics

The vehicle electronics package includes devices that read the vehicle sensors, communicate with the Radiation and Physical Inventory Pallet (RPIP), read operator inputs, and display status information to the operator.

Current
The current vehicle electronics include 1) a processor in STD-bus chassis with various I/O cards; 2) a video scan converter; and 3) a monitor with integrated touch screen. Each one of these items is housed in its own separate box on the lift truck.

The following inputs and outputs from the STD-bus system are currently used:

Num	Type	Usage
7 ea	digital inputs	front/rear slot optos, empty/loaded height optos, boom tip switch, boom tuck switch, boom height switch
2 ea	analog inputs	boom traverse potentiometer, boom rotation potentiometer
2 ea	quadrature inputs	boom height, odometer
2 ea	RS-232 serial ports	communication with touchscreen and pallet payload (RPIP)
1 ea	VGA output	Text overlay to video scan converter

Potential
STD-bus components are no longer available from the original manufacturer. Replacements for some but not all of the I/O cards are available from other manufacturers. Replacement of the entire computer package may be required for any new installations and possibly for the refurbished lift trucks as well. Possibilities

include replacing the STD-bus system with a programmable logic controller (PLC), CompactPCI, or PC/104.

The original video scan converter is no longer available but equivalent equipment can be found. The scan converter is used to overlay text and graphics on the live video from the boom camera on the lift truck.

6.4 Sensors

A number of status sensors are placed on the lift truck so that the operator may be made aware of how the truck is operating and how the inventory is proceeding.

Current
Information about the current lift truck position and configuration is obtained from the following sensors on the truck:

Name	Type
Boom tip	Switch
Mast maximum height	Switch
Boom tucked	Switch
Boom traverse	Potentiometer
Boom rotation	Potentiometer
Odometer	Quadrature encoder
Mast height	Quadrature encoder
Mast height	2 ea Opto switch
Slot position	2 ea Opto switch

Potential
The mechanical switches, potentiometers, and quadrature encoders are widely available items that can be replaced by any functionally equivalent equipment.

6.5 Control Station

The current lift truck does not have an operator control station, since the operator rides on board the lift truck. A control station will be required only if the remotely operated lift truck option is selected.

Current
There is no control station used with the current shielded lift truck because the operator rides on board the truck. Inside the truck, a status display with an integrated touchscreen gives the operator current status and allows the operator to issue simple commands like “Start inventory” by touching icons on the screen.

Potential

A separate off-board operator control station will be used to operate the system if the remote-controlled lift truck option is selected. The control station will enable the operator to drive the lift truck as well as control the inventory process. The control station will receive status information from the truck and display it to the operator, in much the same way the current on-board electronics do.

Appendix A: Memo to Pantex

Sandia National Laboratories
Albuquerque, New Mexico 87185

date: *January 28, 2002*
to: Cassie Turner (Pantex Plant)

from: James F. (Red) Jones and Ron Simon

subject: Issues Relating to Near and Long Term Zone 4 Stage Right Operations

Ron Simon, Wendy Amai, and I discussed issues relating to continued operation on Stage Right in Zone 4. With respect to continued operation of the Stage Right equipment the most significant issues are:

The SLT's are wearing out. According to our local Hyster dealer, the base lift truck should have a useful life of about 20 years provided it is used properly and well maintained. However, the SLT's are equipped with radiation shielding that results in near maximum chassis loading and are used in an environment more severe than that of a normal warehouse. Thus, we would expect that the useful life of the SLT's are somewhat less than 20 years. Since, the SLT's were built in the early 1990's we can reasonably expect increasing maintenance costs with required replacement or major refurbishment within the next two to five years. Although a lift truck could be replaced or refurbished at reasonable cost the main issue is that of the shielding. The radiation shielding is degrading due to the rigors of the operational environment and will likely not refurbishable. It is our understanding that the company that supplied the shielding material for the SLT no longer does so and that the systems integrator that installed it is questionable in their current capability. Thus, fabricating near duplicates or refurbishing existing SLT's may not be a viable option.

One of the three SLT's RPIP interfaces has been damaged and is thus unable to be used in RPIP operations. Another of the SLT's does not posses the interface capability to use the RPIP. Thus, the bulk of workload is delegated to one SLT, which aggravates the SLT life expectancy issue discussed above.

RPIP's have a difficult time surviving the rigors of the Zone 4 operations. During setup operations the RPIP experiences significantly higher dynamic loads than were originally anticipated. Modifications to existing RPIP's have helped but will likely be inadequate in the long term.

From the issues discussed above it becomes apparent that there are pressing short-term issues that should be resolved to assure continued and reliable material movement and inventory capability. Further, there is a very real need to begin planning for the replacement of Stage Right Zone 4 equipment because it is not realistic to believe that the existing equipment will have a serviceable life greater than two to five more years. With this in mind we have put together the following list of short, medium, and long-term items for consideration. This is not intended to be an all-inclusive list but does contain tasks that we feel will have benefit commensurate with cost.

Short-term items are tasks that could be accomplished in a few months that would provide tangible benefit. Please note that cost estimates are very rough and assume that we can leverage infrastructure and personnel from the existing SR2 project. These items are:

Repair the damaged SLT-RPIP interface. This repair would help spread the workload over two SLT's thus helping extend their serviceable life and increasing operational availability. We have not been able to assess the damage but believe a new interface could be fabricated, installed, and tested in the range of $10K-$20K. Potentially, repair of the existing interface could be substantially less depending upon an assessment of actual damage.

Install new monitors in the two SLTs with operator assist/RPIP interface. The existing monitors picture quality is fading which is a typical sign the monitors are wearing out and is to be expected as monitor's age. Replacements are commercially available but given the touch screen capability the monitor's interface is somewhat non-standard. Hence, we anticipate replacement monitors will cost a few thousand per unit plus integration and installation. A round working number would be $10K for both SLTs.

Install boom cameras on the two STLs with operator assist/RPIP interface. Cameras mounted on the SLTs in a manner similar to the SR2 AGV would enhance an operator's ability to perform precision movements making operations more ergonomic and thus potentially reducing wear and tear on the vehicles and equipment. We anticipate procuring and installing these cameras would cost about $15K per vehicle.

Medium-term items are tasks that could be accomplished within a year that would significantly extend the serviceable life of the existing equipment. Medium-term items should be considered as bridging the gap in time between life extensions achievable with short-term items and when long-term solutions could realistically be brought on-line. These items are:

Upgrade the original SLT with operator assist/RPIP interface thus allowing one of the other two SLTs to be retired when appropriate. This task would require installing the feedback sensors, operator assist, and RPIP interface. A significant but strait forward effort would be required to port existing software to available computer platforms due to sunset technology associated with the existing equipment. Another issue is whether the original system integrator for the feedback sensors will be viable. If not, Sandia is fully capable of doing so but not a cost effectively as the original integrator. A very rough estimate of this task is $350K-$525K depending mainly upon the viability of the original integrator.

Upgrade one of the existing AGVs and mobile base station to be RPIP compatible. This option is attractive because RPIP inventories are time consuming and ergonomically unpleasant for the operator and by using the AGV for inventory the SLTs could be reserved for material movement and backup inventory capability. Upgrading the AGV would primarily involve replacing sunset technology items and porting the SR2 GSC. Having studied this option recently feel reasonably confident in the $650K cost estimate.

Design and build a ruggedized RPIP. As mentioned above the dynamic loads experienced by the RPIP during inventory operations are significantly higher than originally anticipated. Modifications to the original RPIP have helped a great deal. However, to completely resolve the issue the basic mechanical design of the RPIP must be revisited. It is our understanding that you have discussed this issue with Dean Mitchell in some detail and cost estimates for this task are best supplied by Dean, but please feel free to contact us if we can assist you on any matter relating to this task.

Long-term items are tasks that will likely take in excess of a year to bring on line and are intended to provide of serviceable and reliable material movement and inventory capability for another 10-20 years. However, simply replacing the existing equipment with like items may not be the best solution. Options include:

Replacing the SLTs with one or more functionally equivalent units. However, since the shielding is likely no longer available, the cost associated with this alternative may or may not be attractive.

A remote control forklift driven by remote operator may be a very inexpensive alternative if a suitable level of performance can be obtained.

A hybrid tele-operated/computer controlled lift truck my provide an excellent balance between performance, ergonomics, and cost but would require some development.

I propose that we conduct a system assessment in order to determine the most appropriate long-term solution from a standpoint of performance, cost, acceptability, etc. Currently, we are attempting to arrange internal Sandia funding to support this task but any additional support Pantex may wish to provide including support from Pantex personnel would greatly facilitate this activity.

If you would like to discuss these issues in more detail, please feel free to contact Red Jones via phone or (e-mail) 505-844-9661 (redjone@sandia.gov) or Ron Simon at 505-844-5214 (rwsimon@sandia.gov).

Appendix B: Interim Refit of AGV

Concepts for Shielded Lift Truck and AGV Refit
April 11, 2002

System Concept

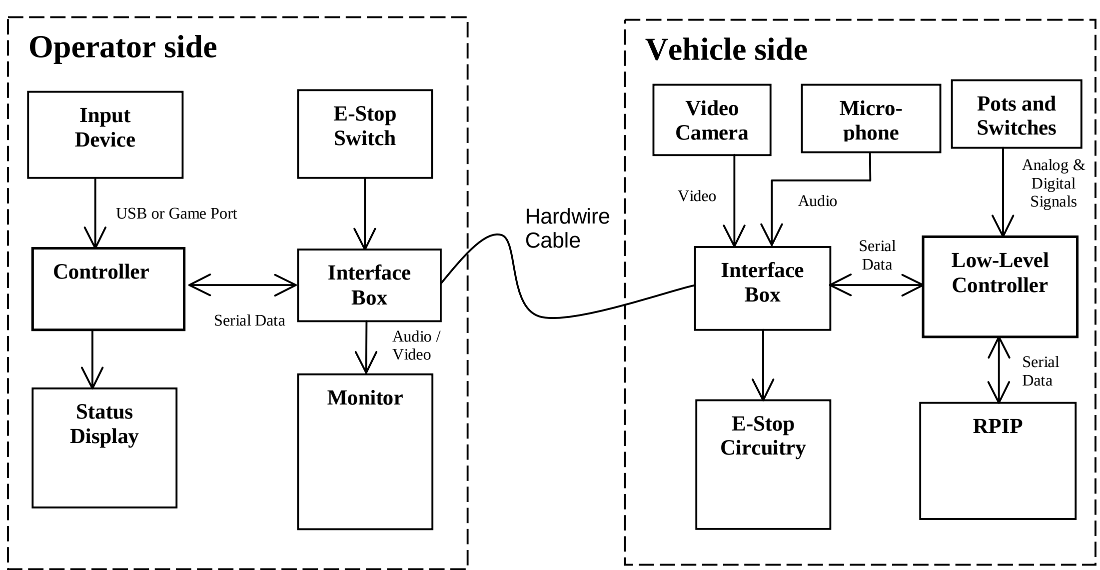
Portable or wearable controller, used by operator outside of the magazine (in vehicle or on apron)
Game-style input device for issuing commands
- drive forward, backward
- raise boom
- traverse, rotate boom (locked out while in magazine)
- steering (locked out while in magazine)
- commence RPIP inventory
- abort RPIP inventory

Live video display from boom camera for alignment
Status from lift truck includes
- lift truck slot (continuous and discrete)
- boom height, traversal, rotation (all continuous)
- boom tucked (discrete)
- boom too high (discrete)
- RPIP status (discrete)

Controller linked to lift truck via hardwire carrying
- bi-directional digital commands and data
- analog audio from lift truck
- analog video from lift truck
- E-stop hardlink

Separate E-stop red mushroom switch
- Deadman switch: circuit broken when switch depressed or hardwire severed

Hardware Block Diagram



Concept of Operations

Lift truck is manually driven to the magazine and parked on apron. After ramp is set up, the lift truck can be driven manually onto the ramp. Operator unrolls the hardwire (from a reel, watch for twisting) and connects the far end to the interface box on the lift truck. The components of the controller are contained within a padded back pack. He connects the near end of the hardwire to the interface box inside the back pack. He pulls out the game-style input device and turns on the controller itself. At this point, the operator can drive the lift truck using direct visual feedback, a useful mode for just moving the truck around and positioning the boom.

The RPIP initialization is completed. To perform inventory operations with the controller, the operator pulls the monitor out of the back pack and sets it up in convenient sight. He plugs the monitor power adapter into the cigarette lighter socket and turns it on. If the lift truck is on, the monitor will display live video from the boom camera on the truck. The operator drives the lift truck to the pallet turner slot. Using the game controller, the operator indicates to the truck that it is at the turner slot. The status display will indicate the slot to drive to and height to raise the boom, as reported by the RPIP. The operator drives to the given slot location, using the status display. The operator raises the boom, if required, to reach the location as recommended by the RPIP, again using the status display for feedback. Then, using the live video monitor, the operator positions the truck and boom so that the RPIP is facing the pallet squarely. The operator commences the inventory. During the RPIP measurements, the operator watches the status display for messages from the RPIP. The operator can abort the inventory at any time. Upon completion of the measurements at that location, the status display will show the success or failure the inventory.

As the truck moves into the magazine, the hardwire plays off the reel. When the truck is being backed up, someone must stand by to roll the hardwire back onto the reel. The E-stop functions as a deadman switch, normally closed. When the E-stop is activated or the hardwire is cut, the circuit is opened and the vehicle is safed by bringing it to a stop. (What about the RPIP?)

Controller Implementation Concepts and Discussion

PC104

PC104 in rugged, self-contained IDAN form-factor. External power supply or battery pack. Separate displays for status and video. Can run a variety of operating systems.
Manufacturers: RTD Systems, Ampro.

PDA

PDA serves as controller and has integrated display for status. Use PCMCIA cards for serial port and game port (or USB). Built-in buttons available for input. Displays look good even in direct sunlight.
Manufacturers: Numerous -- Compaq, HP, Palm

Wearable

Wearable computer has separate display for status. This display might also be used for live video display. Use PCMCIA card for serial port; some wearables have built-in USB support.
Manufacturers: ViA, Xybernaut

Notebook, portable

Notebook serves as controller, has integrated display for status, and can possibly display live audio/video. Use integrated serial port for data, USB port for game controller input.
Manufacturers: Numerous notebook makers. Dolch, PGI, CyberResearch for portables.

Custom ruggedized controller

Single-board computer with integrated display and touchscreen. Box serves as controller and status display. Use integrated serial port for data, USB port for game controller input. A custom enclosure may have to be designed to hold the integrated computer / display.
Manufacturers: Advantech, Computer Dynamics, CyberResearch

Selection of a controller for the lift truck and AGV refit must take into account two factors: usability of the controller, and ease of development. Usability is linked to physical aspects such as size, weight, module count, ruggedness, power source, type and layout of controls, and type and layout of status displays. Ease of development is crucial under time constraint, which seems likely for the AGV refit. It will be less of a concern for the long-term lift truck refit. Ease of development is linked to use of familiar operating systems and device driver support for peripherals. Long-lead-time items such as anything that is custom-built can also be problematic in a time-constrained environment.

Controller	Module count	Ruggedness	Power	Shipped OS	Comments
PC104	4: CPU, power, status, video	high	external DC power supply	DOS, Windows	IDAN is expensive
PDA	2: CPU, video	medium	battery or external DC	WinCE, Palm	Does not authenticate individual users
Wearable	3: CPU, status, video 2: CPU, status / video	high	battery or external DC	Windows	
Notebook	2: CPU, video 1: CPU	low to medium	battery or external DC	Windows, Linux	
Portable	2: CPU, power, video 2: CPU, power	medium to high	external AC	Windows	Expensive. Need inverter to provide AC.
Custom	3: CPU, power, video	medium to high	external AC	Windows	Need inverter to provide AC. Custom pkging.

Communication Concepts and Discussion

Fiber optic

Single fiber carries data, audio, and video. Transceiver at each end converts between fiber and analog/digital signals. Transceiver requires external power source.
Manufacturer: Optelecom

Serial + analog audio / video

Cable consists of three smaller cables in parallel, one each for serial data, analog audio, and analog data. Connect directly from hardwire to the end devices, no transceiver or external power needed.
Manufacturer: (custom cable)

Communication link	Cable	Comments
Fiber optic	Light weight, widely available	One transceiver required on each end. Additional cables required to connect between transceiver and end device. Maximum data rate is 128 kilobaud.
Serial, audio, video	Heavier, custom cable	Maximum data rate is 115.2 kilobaud. Serial communications range may be limited.

Video Input

Video input to notebooks does not seem to be as prevalent as it once was. New technologies such as USB, FireWire, and PCMCIA video capture and TV tuner cards seem to have eliminated the necessity of dedicated RCA-jack video inputs. Searching for notebooks supporting a built-in video input port turned up lots of dead or outdated links (1999 and 2000), or foreign companies (British and Taiwanese).

Built-in video input port

It seemed that Gateway made a Solo notebook docking station that had an RCA jack for video input, but unable to confirm that.

PCI and USB

TV tuner cards might have provided a means for video input. The ATI TV-Wonder (PCI and USB), Matrox Marvel G450 eTV (PCI), and Hauppage WinTV (PCI and USB) are examples. The ATI TV-Wonder supports video capture but only from the TV. There is no RCA-jack for video input. The Matrox eTV card is available only in PCI format, so is unsuitable for notebook use. It does have RCA jacks for audio and video input. The Hauppage WinTV also allows video input from an arbitrary video source.

PCMCIA

The Cutting Edge Imaging Solutions VCE-01 (Video Capture Essential) is manufactured in Germany, but it is re-sold by a number of vendors in the States.

Recommendations

To speed development to support a demonstration at Sandia this year, I recommend using a Windows environment (versus WinCE, PalmOS, Linux, QNX) because of developer familiarity and the availability of hardware drivers.

The control station should be a laptop with a game-style input device, and video coming directly into the notebook and displayed in a separate window. Two alternatives are available if video cannot be displayed in a separate window on the laptop or if performance is poor: 1) Use a desktop with a frame grabber. 2) Use a separate external monitor to display the video (hardware-only solution). If option 1 is chosen, then we should use a USB-based framegrabber to allow the software to be ported to a notebook with minimal changes.

For the hardwire link itself, the Optelecom 9716 fiber optic transceiver costs about $1500 each and ships within a month of order placement. For demonstration purposes, it can be plugged into wall power so a custom power supply need not be designed. Cables to connect the fiber optic transceiver to the final outputs (video, audio, and data) can be purchased pre-made or fabricated on-site.

Appendix C: NAC International Shielding Documentation

Sandia National Laboratories

Operated for the U.S. Department of Energy
by
Sandia Corporation

Albuquerque, New Mexico 87185-1008

Date: June 18, 2002

to: Wendy Amai

from: Ron Simon
SNL, Dept. 15272

subject: Zone 4 Cost Survey Information

This memorandum will discuss the information I have gathered in an attempt to estimate the cost of various options for ensuring the continuing capability of Pantex Zone 4 Operations. The areas discussed will include the following options:

1. Refurbishment of current SFLs,
2. Procurement of new SFLs.
3. Refurbishment/replacement of current shielding.
4. Development/Procurement of new spectra type shielding

To properly estimate shielding costs, it was necessary to track down the original shielding provider. Though the company is no longer in business, the technology is still available through NAC International, and would be produced by individuals with experience resultant from the original shielding procurement for the SFLs. The original drawings exist for the current generation of lift trucks in use at Pantex and would be utilized to produce the next generation of shielding if the current trucks are simply refurbished. The shielding will be of the same formulation namely a 10 cm. thick NS-4-FR epoxy loaded with 18.5 % Tungsten metal. Cost for providing the current shielding package is $118,500. This includes production of new molds, and installation of the shielding onto the vehicle. Not included are the following:

1. Shipping (total weight approximately 9,300 lbs.).
2. Sandia provided machining required to achieve final part dimensions.

If this same shielding were to be procured for new generation lift trucks, an additional charge of approximately $4,300 would be required to provide new drawings. The NX30MH differs in some physical parameters from the NX30AH. This information is provided in Attachment 1 from NAC International.

A cost estimate is included in Attachment 2 for the development and procurement of newer lighter shielding which will provide equal shielding factors to the operator. It is based on the actual radiation measurements of the environment inside the hottest magazine in Zone 4. Anticipated composition of this shielding would be a 3 mm layer of cadmium melded to a 3 mm layer of stainless steel. Advantages are weight (approximately 1500 lbs. vs. 9000 lbs.) and mechanical properties (machineability, and structural integrity). Drawbacks are that it would require more development time and money, though it is possible that this can be minimized using current drawings. Procurement cost of Cadmium is approximately $60,000 per vehicle. It is only available in 4 inch x 60 inch strips. We believe that diffusion bonding of layers of cadmium and stainless steel is a possibility, and are also investigating epoxy joining, and cold or thermal spraying. Epoxy joining is probably the most cost effective procedure, and would still yield a superior material to the Bisco with respect to machineability and durability in this application.

A cost estimate is included for refurbishment of the existing SLTs. It is determined using a work breakdown by task and time required to perform each task. Hyster quoted an hourly rate of $56.00 per hour, and parts estimates are generated using accepted loading rates. The labor hour total of 77.5 is multiplied by the hourly rate to yield a cost of $4,340 per vehicle. Part estimate is between 1 and 1.5 times the labor cost for each vehicle, and amounts to an additional $4,340 to $6,510. Total estimated cost for each vehicle refurbishment is from $8,680 to $10,850.

Costs not included in this estimate are as follows:

1. Removal of shielding (provide access to truck).
2. Shipping of the SLT to Stewart and Stephenson (Hyster local rep).
3. Unknown major problems (small probability).

This information is provided in Attachment 3 to this memorandum.

A cost estimate is also included for procurement /development of new lift trucks to replace the older generation of trucks currently being used. New lift trucks do represent an upgrade to the current vehicles in many of the control aspects (accelerator pedal, rocker switch controls and software/computer control) providing improved functionality and maintainability. This information is contained in Attachment 4 to this memorandum. Estimated cost of the base vehicle required to develop the Tele Operated Material Movement/Inventory Vehicle is $112,000. It is important to note that development of this specific option is likely to provide a multiplier of 10x to the base vehicle cost. Successive vehicle procurements would approximate the base vehicle cost.

(Note: Attachments referenced in the above memo are not included in this document)

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